

SanDisk Application Note

Using the MultiMediaCard in SPI Mode with an 80C51 Microcontroller



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1.0 Introduction to the SanDisk MultiMediaCard

The SanDisk MultiMediaCard is a very small (32mm x 24mm x 1.4mm), non-volatile removable flash storage card. It's designed specifically for applications requiring small form factor, low power and low cost. The MultiMediaCard is the ideal storage card for portable devices like cellular phones, pagers, MP3 players and voice recorders.

The MultiMediaCard includes an on-card microcontroller, which manages the interface protocols, data storage and retrieval, Error Correction Code (ECC), defect handling, diagnostics, power management and clock control. All device and interface configuration data are stored on the MultiMediaCard. The MultiMediaCard has a seven pin serial interface, which allows for easy integration into any design regardless of the microprocessor/microcontroller used.

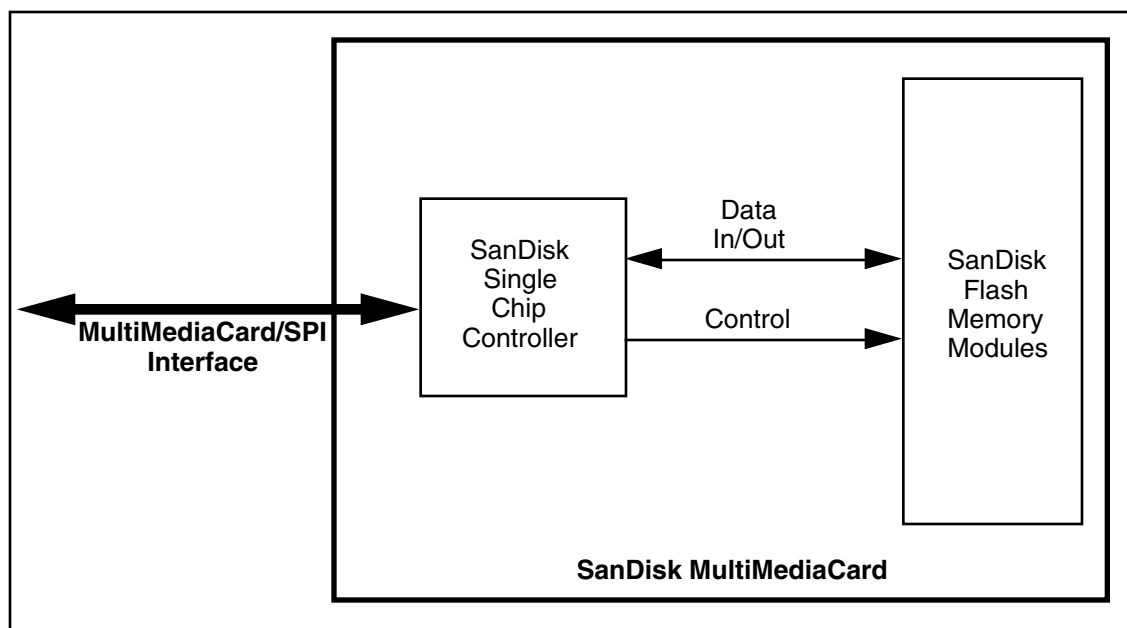


Figure 1-1 MultiMediaCard Block Diagram

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1.1 MultiMediaCard Bus Interface

The MultiMediaCard has a seven pin interface that can be set to run in either MultiMediaCard or in SPI mode. The following table defines the pins for both modes.

Table 1-1 MultiMediaCard Pin Description

Pin Number	MultiMediaCard Usage	SPI Usage	SPI Description
1	RSV	CS	Chip Select (Active Low)
2	CMD	Data In	Host to Card Command and Data
3	VSS1	VSS1	Supply Voltage Ground
4	VDD	VDD	Supply Voltage
5	CLK	CLK	Clock
6	VSS2	VSS2	Supply Voltage Ground
7	DAT[0]	Data Out	Card to Host Data and Status

1.2 The MultiMediaCard's SPI Mode

The Serial Peripheral interface (SPI) is a synchronous serial interface originally found on Motorola's microcontrollers. The SPI bus consists of the following four signals:

- CS: Host to MultiMediaCard chip select signal.
- CLK: Host to MultiMediaCard Clock.
- DataIn: Host to MultiMediaCard data in signal.
- DataOut: MultiMediaCard to Host data out signal.

All data transfers in the SPI mode are multiple of 8-bit bytes and always byte aligned to the CS signal.

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1.3 The MultiMediaCard's Electrical Interface

The MultiMediaCard's bus operates at voltage range between 2.7 to 3.6 VDC. If the host uses a 5VDC microprocessor/microcontroller, the voltage ranges must be translated between the host and the MultiMediaCard. The following simple circuits should perform the required task.

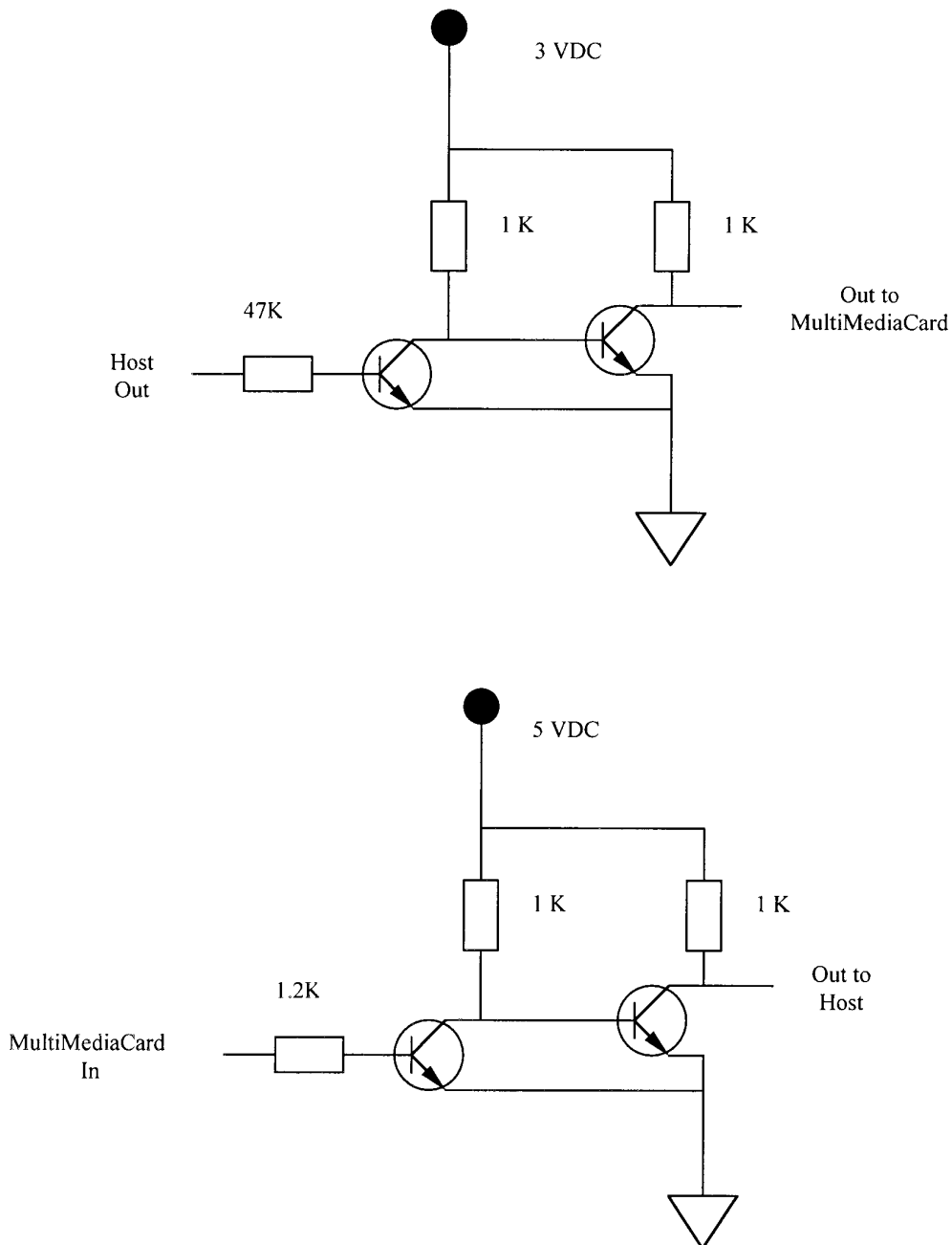


Figure 1-2 MultiMediaCard Circuits

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1.4 The MultiMediaCard's Command Format

The MultiMediaCard's command is six bytes long. The detailed description of the command is as follows:

0	1	bit [5:0]	bit [31:0]	bit [6:0]	1
Start bit	Host bit	Command	Argument	CRC7*	End bit

Commands and arguments are listed in the MultiMediaCard Product Manual.

* The 7bit CRC is calculated using the standard CCITT polynomial: $G(x) = x^7 + x^3 + 1$.

$M(x) = (\text{Start bit}) \cdot x^{39} + (\text{Host bit}) \cdot x^{38} + \dots + (\text{last bit before CRC}) \cdot x^0$.

$\text{CRC7 [6:0]} = \text{Remainder} [(M(x) \cdot x^7) / G(x)]$.

2.0 Basic Diagram of the Digital Audio Recorder

Figure 2-1 shows the block diagram of the Digital Audio Recorder. The Recorder basically consists of three main sections. The first section being the audio input section which consists of a microphone, an operational Amp and an Analog to Digital Converter (ADC). Section two is the controller section. Intel's 80C51 is the microcontroller used in this design which interfaces to the MultiMediaCard and processes all the audio sample data. The third and final section is the audio output section which contains the Digital to Analog Converter (DAC) and the audio amplifier.

2.1 Audio Input

The analog input section uses a generic Elektret microphone as the audio input device. A LM324 Operational Amplifier then amplifies and filters the signal from the microphone to the required level by the Analog to Digital Converter (ADC). The signal is then fed into a National Semiconductor ADC0804LCN ADC. The ADC0804LCN is configured in a free running mode and connected to Intel's 80C51 Address/Data bus.

2.2 Digital Control

The digital control section is centered around Intel's 80C51 microcontroller and the supporting ICs. The microcontroller is configured in an external mode that allows for external RAM and ROM access. The 80C51 controls all user input and output, audio sampling and storing, sample retrieving and playback, and the MultiMediaCard's SPI interface.

2.3 Audio Output

The main component in the audio out section is National Semiconductor DAC0830LCN. The DAC is configured in a feed-through mode. The analog output of the DAC is then fed to a LM324 Operational Amplifier to be filtered. After the output is filtered, it's then fed to the final audio amplifier stage. The audio amplifier stage is based on the National Semiconductor LM386N-1 single supply audio amplifier. The LM386N-1 is capable of driving an 8 ohm speaker with adequate audio level.

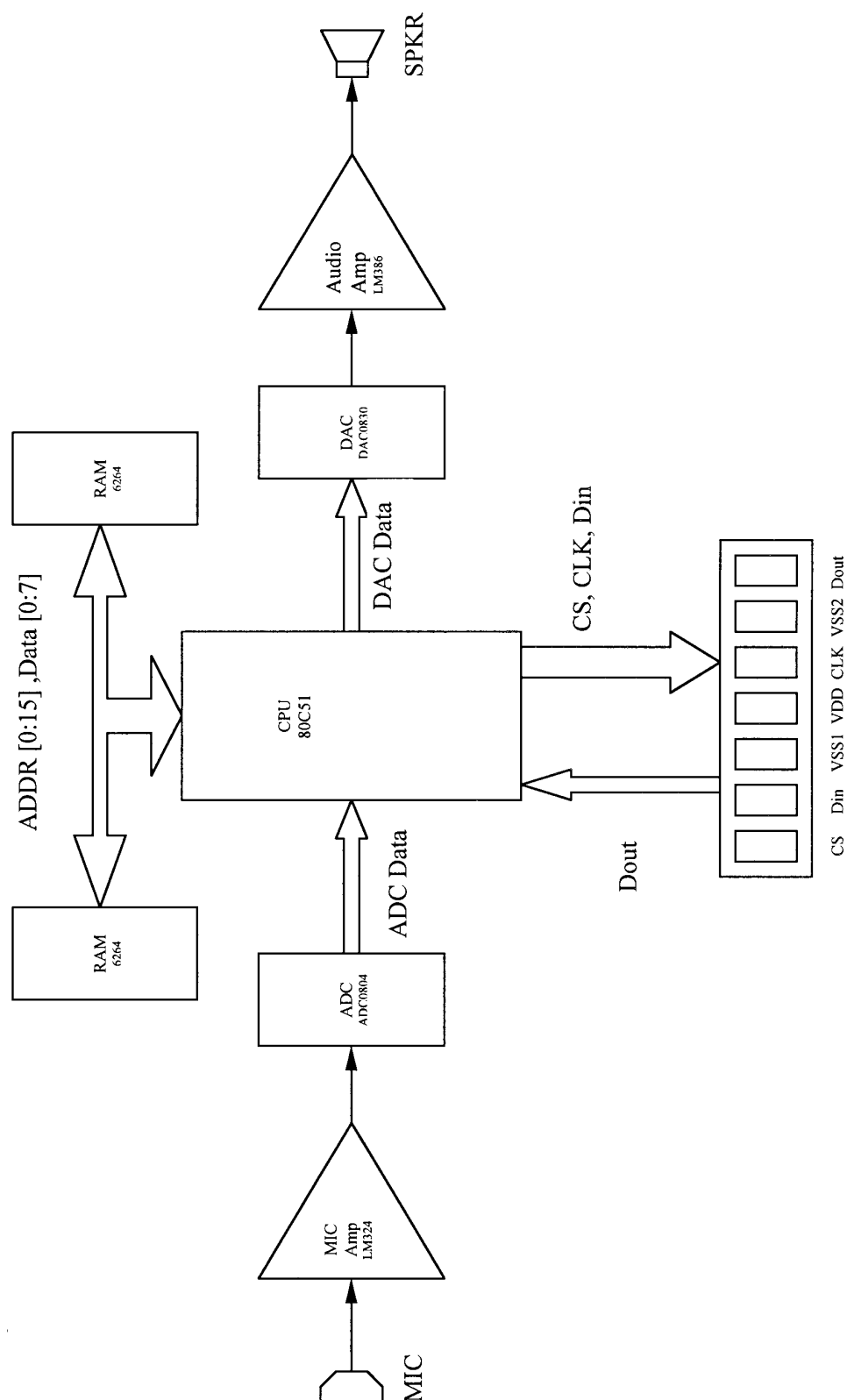


Figure 2-1 MultiMediaCard Connector

3.0 Basic Digital Audio Recorder Operation

When powered up, the recorder initializes the MultiMediaCard to SPI mode and updates the LED display to indicate that the recorder is in the Ready mode. In the Ready mode, the user can select to either start the record or the playback process by pressing the corresponding buttons. The Recorder does not check whether the data on the MultiMediaCard is audio when the playback button is pressed. It will just update the LED display to indicate it's playing back and start playing at the first data block of the MultiMediaCard. When all the data on the MultiMediaCard is played back, the recorder will stop and go into the Ready mode. When the record button is pressed, the Recorder updates the display to indicate it's recording and starts recording on the first data block of the MultiMediaCard. When the MultiMediaCard is full, the recording will stop and the recorder will go into the Ready mode. Again, the recorder does not check whether there is previous data on the MultiMediaCard before writing over it.

Many message management features can be added to this reference design by modifying the program code and/or the circuit. The main goal of this design is not to have a CD quality audio recorder with message management capability, but rather to prove that designing applications around SanDisk's MultiMediaCard in SPI mode is very straight forward.

3.1 Initialization to SPI Mode

Once the Recorder is powered up with the MultiMediaCard inserted, it will initialize the MultiMediaCard to the SPI Mode. The initialization process is as follows:

- Send 80 clock pulses to start bus communication.
- Assert the chip select (CS) pin, (active low).
- Send CMD 0
- Send 8 clock pulses of delay
- Wait for valid response
- Send 8 clock pulses of delay
- Send CMD 1
- Send 8 clock pulses of delay
- Wait for valid response
- Send 8 clock pulses of delay
- Repeat from CMD1 until response shows ready

Figure 3-1 shows the flow chart for the initialization process.

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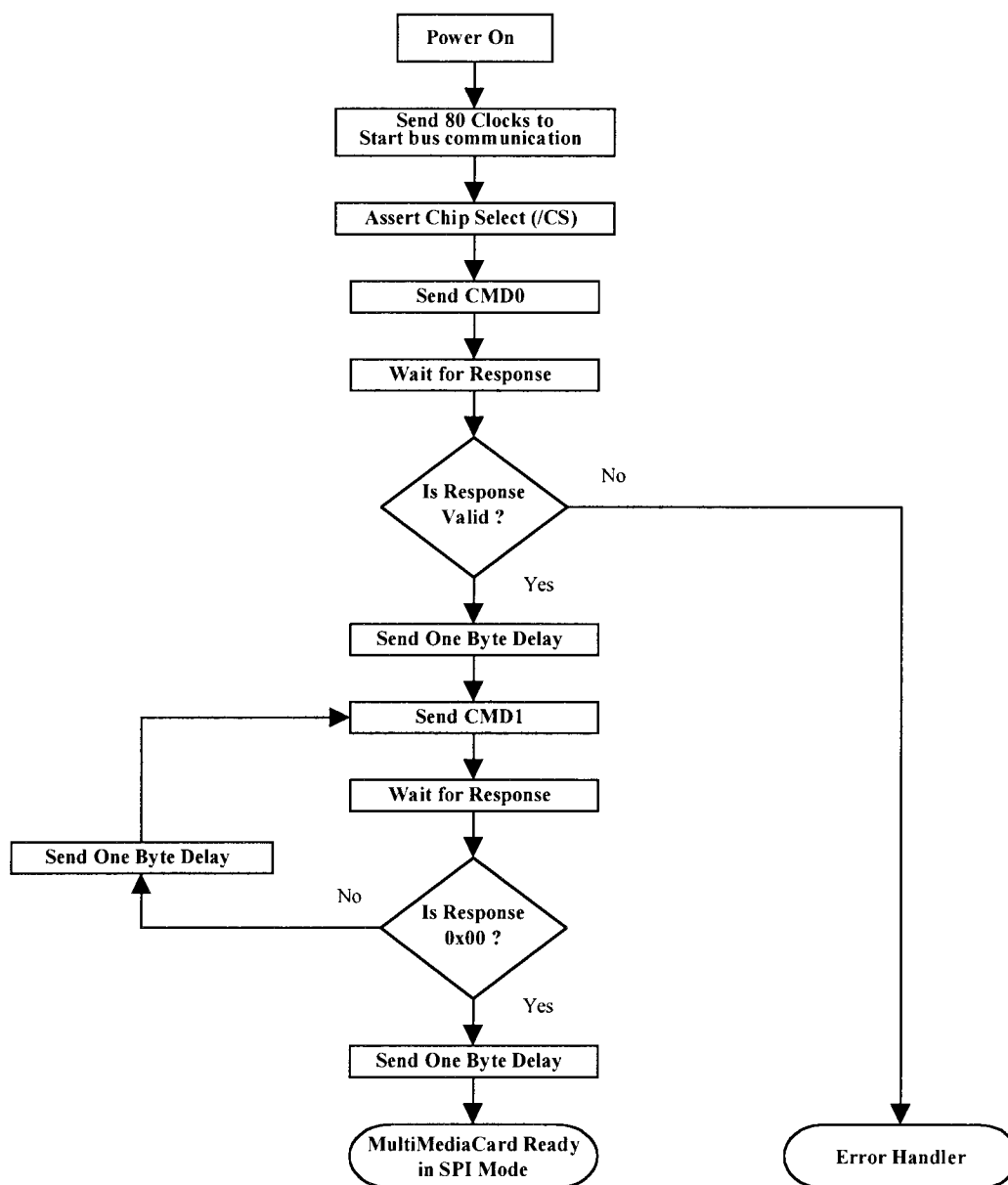


Figure 3-1 Initialize and Switch to SPI Mode

3.2 *Recording*

Once the Recorder is initialized to the SPI mode, it waits for the user to press either the record or playback button.

If the record button is pressed, the recorder starts recording by sampling the microphone input every $100\mu\text{S}$ (10 kHz sampling rate) and storing it into the buffer. Since the sampling rate is 10 kHz, the highest frequency that can be reproduced is 5kHz, which is more than adequate for voice recording.

At the same time that the Recorder is sampling the input, the 80C51 microcontroller is preparing the MultiMediaCard for a write block operation. When the MultiMediaCard is ready for the write block operation, sample data from the buffer is sent to the MultiMediaCard and written into memory. Once all the MultiMediaCard's memory blocks are full, the record operation will stop and the Recorder will go to the Ready mode.

Figure 3-2 on the following page shows a flow chart of the recording process:

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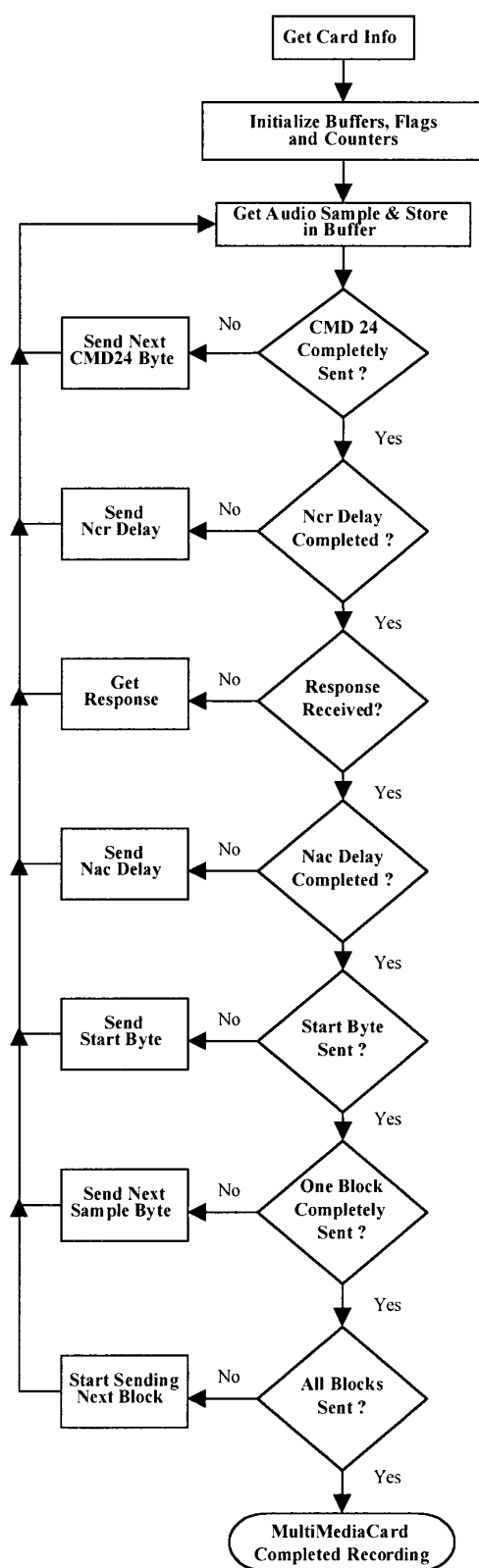


Figure 3-2 Sample Audio and Record Flow

3.3 Playing Back

When in the Playback mode, the recorder starts by preparing the MultiMediaCard for a read block operation. Once the MultiMediaCard is ready for the read block operation, the first block of sample data is read and stored into the sample buffer. Now the recorder will start by taking one sample from the buffer, every $100\mu\text{S}$, and sending it to the DAC to reproduce the stored audio.

While the recorder is sending sample data to the DAC, it's also preparing the MultiMediaCard to read the next block of sampled data. Once all the blocks are read and sent out to the DAC, the playback operation will stop and the Recorder will return to the Ready mode.

Figure 3-3 on the following page shows a flow chart of the playback process:

Using the MultiMediaCard in SPI Mode with an 80C51 Microcontroller

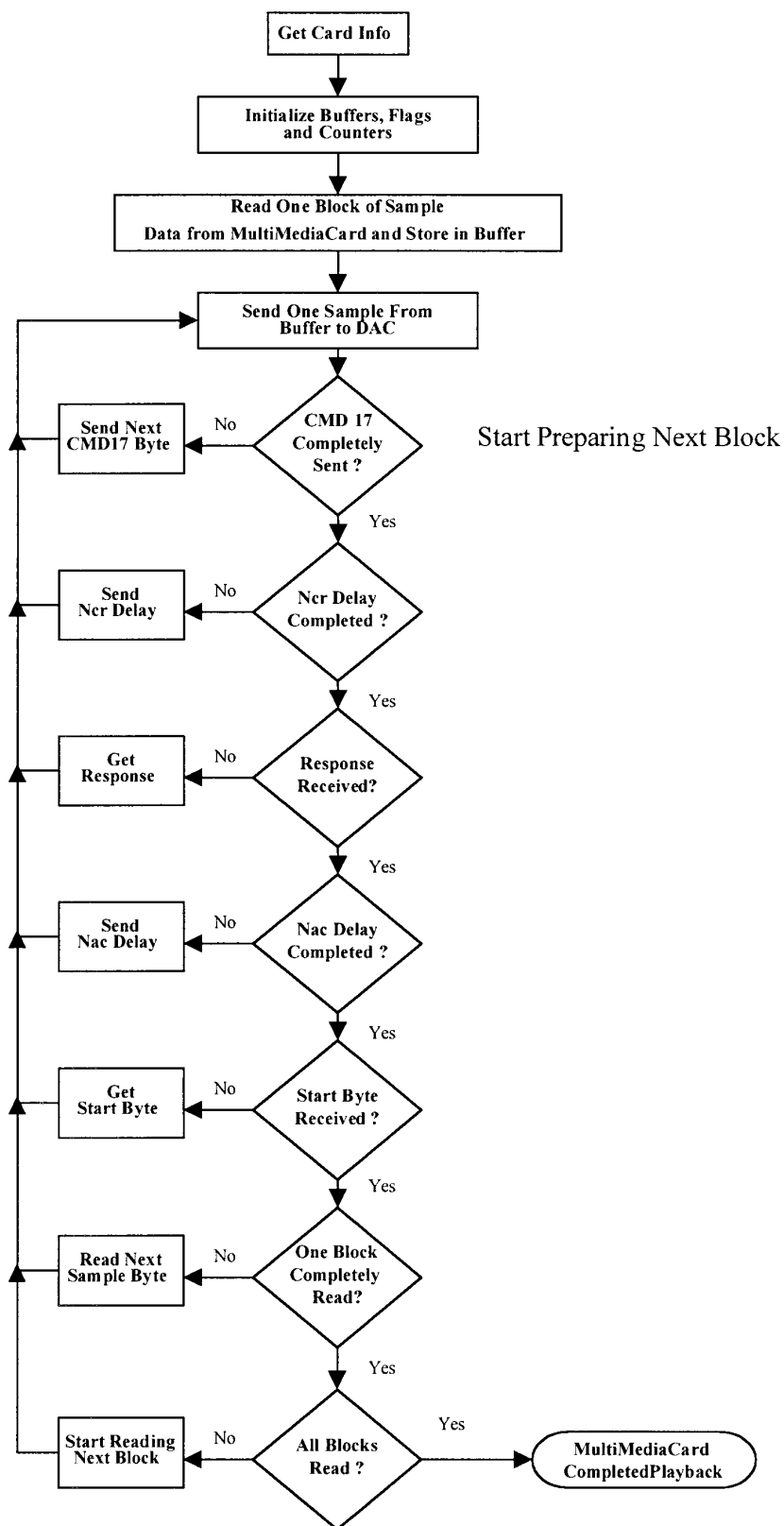


Figure 3-3 Read Sample Data and Play Back Flow

4.0 Interfacing Intel's 80C51 to SanDisk's MultiMediaCard

4.1 Intel's 80C51 Microcontroller

The microcontroller used in the Digital Audio Recorder, DS87C520, is based on Intel's 80C51 core. The DS87C520 microcontroller is a pin-to-pin compatible enhanced version of Intel's 80C51 made by Dallas Semiconductors. The microcontroller features 4 clock cycles/machine cycle compared to 12 clock cycles/machine cycle for the 80C51 and it can run from DC to 33MHz instead of DC to 12MHz. Figure 4-1 shows the pin-out of the DS87C520.

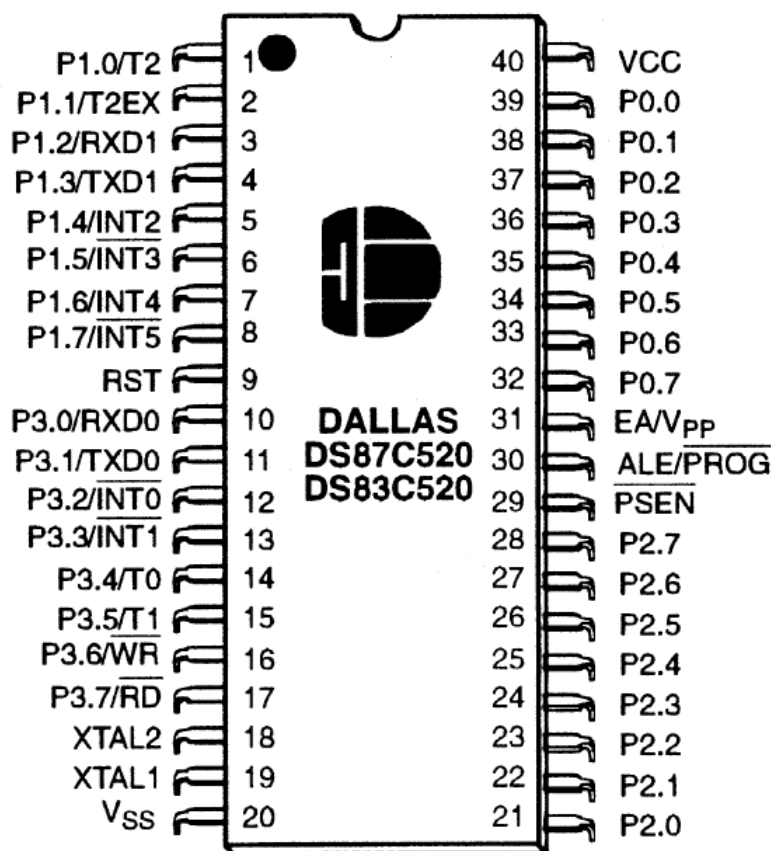


Figure 4-1 Pin-out of DS87C520

Four I/O lines are needed to interface the DS87C520 to the MultiMediaCard. The four I/O lines need to have their logic levels translated from 5VDC logic to 3VDC logic since the microcontroller operates on 5VDC and the MultiMediaCard on 3VDC. The circuits in section 1.3 will be adequate to translate the voltages. P1.4 to P1.7 I/Os of port 1 are used as CS, CLK, Din, and Dout respectively to interface with the MultiMediaCard.

4.2 Port 0 and Port 2

Since the DS87C520 microcontroller is configured for the external memory mode, port 0 (AD0 – AD7), in conjunction with /RD, /WR, ALE, and PSEN pins, provides the low order address byte and the data byte for the external code and data memory.

Port 2 (A8 – A15) provides the high order address byte for the external code and data memory. A 74HC138 de-multiplexer is used to de-multiplex the higher order address byte to access the Analog to Digital Converter (ADC), the Digital to Analog Converter (DAC), RAM, ROM, and the user interface.

5.0 Digital Audio Recorder Memory Map

The Digital Audio Recorder's RAM and ROM are located external to the microcontroller. The following memory map shows where ROM, RAM, and the other blocks of the Digital Audio Recorder are accessed.

BFFF	LED DISPLAY
A000	
9FFF	ADC
8000	
7FFF	DAC
6000	
5FFF	KBD
4000	
3FFF	RAM
2000	
1FFF	ROM
0000	

Figure 5-1 Digital Audio Recorder Memory Map

5.1 RAM

The RAM used in the Digital Audio Recorder is the standard 6264 (8K x 8) SRAM. The pin-out for the 6264 is shown in figure 5-2. The SRAM is accessed at 0x2000 to 0x3FFF. The Recorder mainly uses the SRAM as a buffer for the sample data.

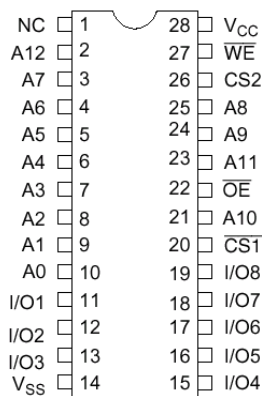


Figure 5-2 Pinout for 6263 RAM

5.2 ROM

The Recorder's ROM that holds the firmware is external to the DS87C520 microcontroller. Again the ROM is a standard 27C64 (8K x 8) EPROM. The ROM on the Recorder is located at (0x0000 to 0x1FFF) in the memory map. The following figure, Figure 5-3, shows the pinout for the 27C64 EPROM.

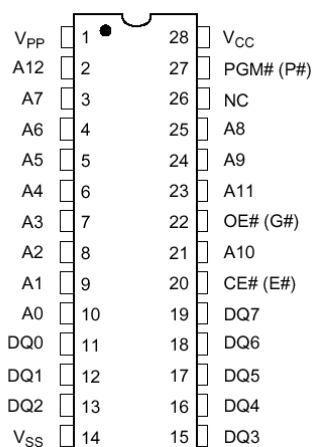


Figure 5-3 Pinout for the 27C64 EPROM

5.3 ADC

National Semiconductor's ADC0804LCN was the Analog to Digital Converter selected for this reference design. The ADC0804LCN has an 8 bit resolution and is capable of one sample per 100 μ S. It can be operated with a single 5VDC supply and has an on-chip clock generator. The ADC is configured in a free-running mode using the on-chip clock generator and it is mapped out at 0x8000 to 0x9FFF. Figure 5-4 shows the pinout for the ADC0804LCN.

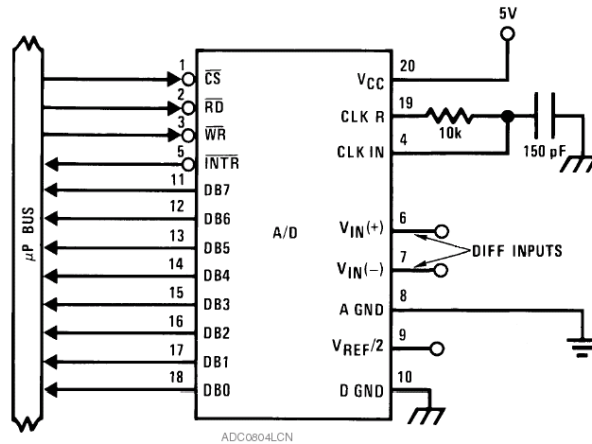


Figure 5-4 Pinout for the ADC0804LCN

5.4 DAC

The Digital to Analog Converter used in this design is also National Semiconductor's. The DAC0830LCN has an eight-bit resolution, a settling time of 1 μ s which is more than adequate for audio sampling, and can be operated from a single 5VDC supply. The DAC in the design is configured in a voltage output mode, which turns the Vref pin into an output and the Iout pins into inputs. The following figure shows the pinout of the DAC0830LCN for reference.

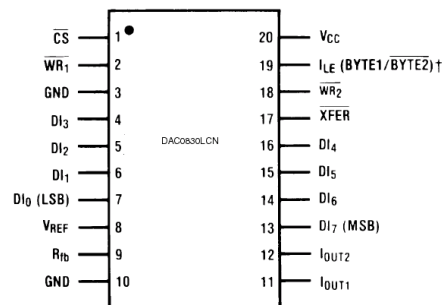


Figure 5-5 Pinout of the DAC0830LCN

5.5 User Input and Output

Since the Digital Audio Recorder has only two main functions, record and playback, the user input and output circuits are very simple and straightforward. The input has only two momentary push buttons, one to select the playback mode and the other to select the record mode. The output is a 7 segment LED display that shows "P" for the playback mode and "r" for record mode. When the Digital Audio Recorder is powered up, the LED display will show "0" if the MultiMediaCard initialization was completed without errors and "1 to 9" if an error was encountered.

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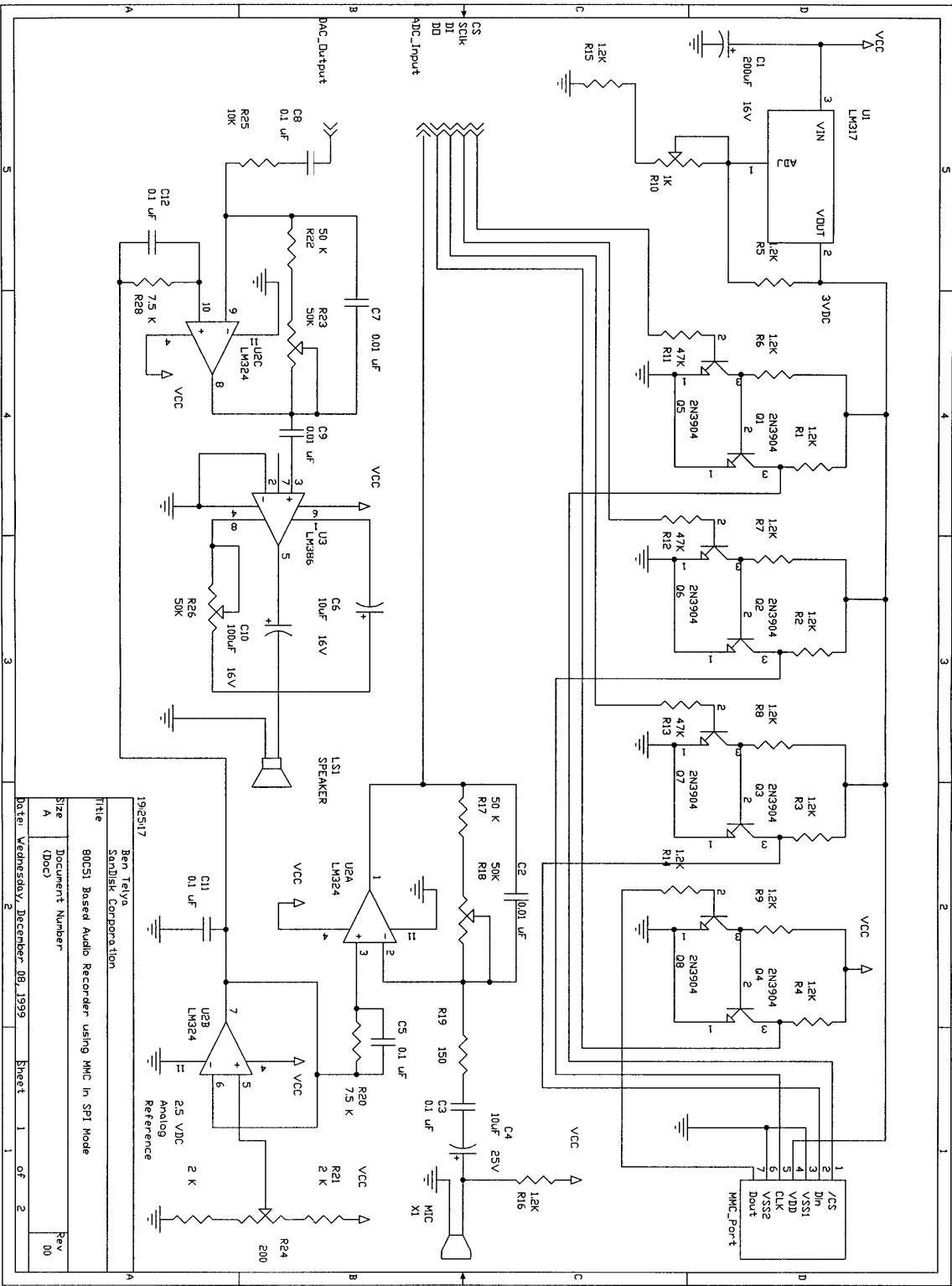


Figure 5-6 Schematic

Using the MultiMediaCard in SPI Mode with an 80C51 Microcontroller

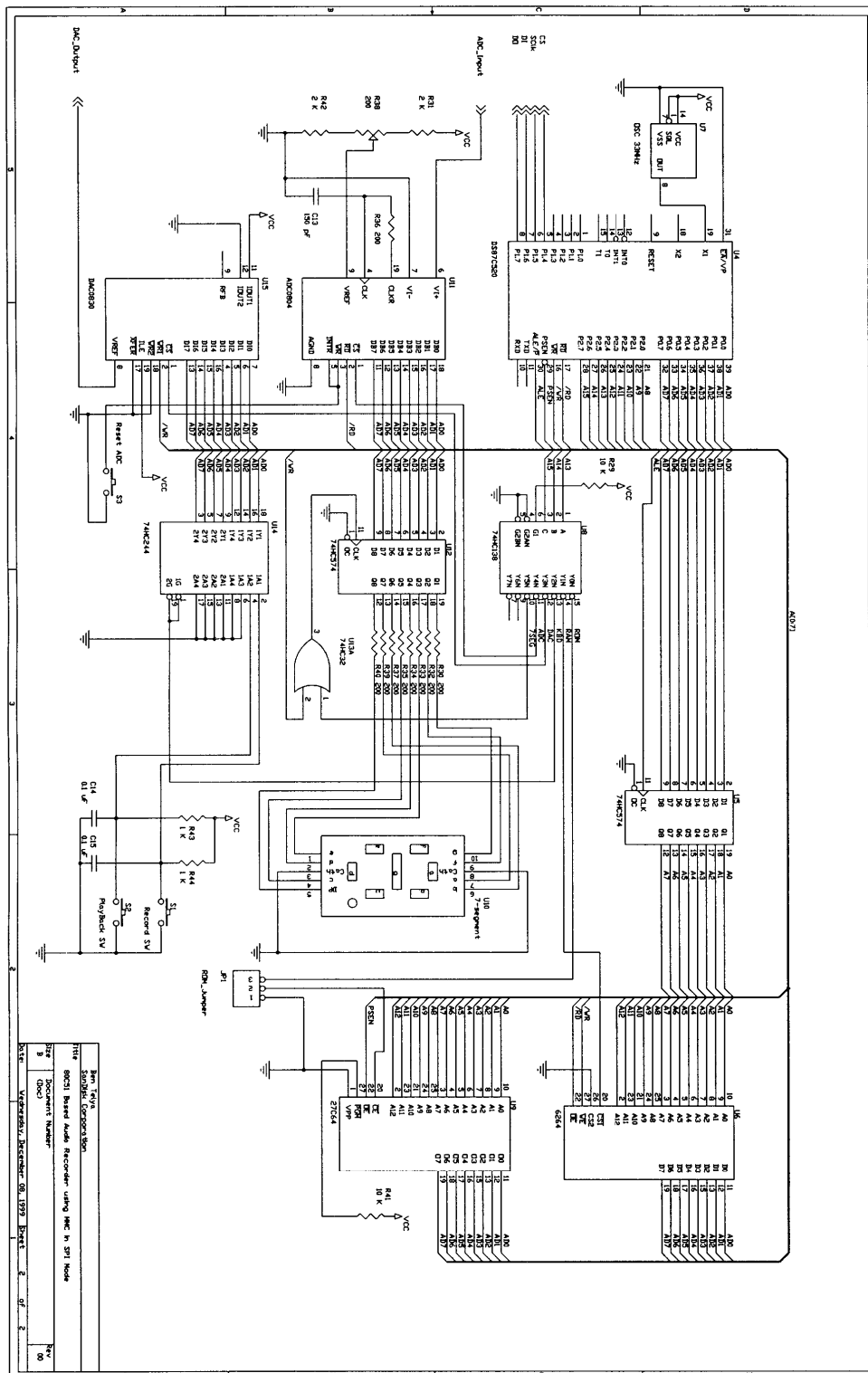


Figure 5-6 Schematic